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(54) **Method and apparatus for detecting a fault of a control valve assembly in a control loop**

Verfahren und Vorrichtung zur Ermittlung eines Fehlers einer Steuerventilanordnung in einem Regelkreis

Méthode et appareil pour détecter un défaut d'un dispositif de vanne de commande dans une boucle de régulation

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Description

[0001] This invention relates to a method for detecting a fault of an automatically operated control valve assembly in a control loop so that data consisting of several values of the control signal and corresponding values of the position of the control valve is measured and recorded. The invention also relates to an apparatus for detecting a fault in an automaticlly operated control valve assembly, the valve assembly including a control valve, an actuator and a digital positioner, as well as means for measuring, transferring, recording and processing data.

[0002] The importance of advanced maintenance of control valves has further increased when it is desired to decrease maintenance costs, to increase safety and to have the processes functioning accurately while saving energy and reducing waste. New positioners based on digital technology give better possibilities for this. On the other hand, the development of new data transfer buses gives better possibilities for transferring diagnostic data from the field device to the automation system and for transmitting measurement data from sensors outside the control valve to the control valve.

[0003] A control valve and its operation is known and need not be described here in detail. A quarter turn valve can be for instance a ball valve or a butterfly valve. Examples of a ball valve are disclosed for instance in US patent 4 747 578. A control valve is actuated by means of an actuator which turns the stem of the closure member between open and closed positions. An actuator can be operated by means of a cylinder-piston device which in turn is regulated by means of a regulation valve. A valve positioner operates the actuator in response to a control signal.

[0004] Various systems have been developed for the diagnostics of control valves, and these systems can be used for measuring and testing the valves in order to detect faulted operation. US patents 5 272 647, 5 233 512, 4 509 110, 4 213 175 and 5 129 418 all describe various diagnostic arrangements. However, they do not enable the location of the fault to be detected.

[0005] EP 315391 discloses an online valve diagnostic monitoring system to monitor valve operation and sense the wear and on page 3, lines 46-52 it is stated that the valve comprises a plurality of sensors (24, 31, 34, 36) associated with each valve, each sensor simultaneously sensing a different operational characteristic of the valve, to produce corresponding different sensor status signals; data acquisition means (40, 42) for transmitting the sensor signals for processing; characterized by processor means (44, 46) for processing the sensor signals to produce processed signals and for comparing the processed signals to produce a diagnosis of the valve; and output means (52) for indicating the diagnosed condition of the valve. A plurality of sensors are described as being specifically and additionally provided and the signals of these sensors are processed by means of a specific processor, and the condition of the valve is indicated by comparing these processed signals.

[0006] Some systems, such as the one described in US patent 5 197 328, even make it possible to locate the reason of the faulted operation, but it requires a complicated measurement arrangement and a lot of measurement data from the various components of the control valve assembly, that is from the valve itself, the actuator and the positioner.

[0007] The object of the present invention is to provide a method and an apparatus which are able to independently draw conclusions of faulted operation and to locate the faulted component by means of a simple measurement arrangement and by using a mathematical model of a control valve assembly and a data transfer bus. A mathematical model describing the dynamics of a quater-turn control valve is disclosed in the ISA paper 92-0408, Vol. 47, Part 2, 1992, pp. 1341-1353; J. Pyotsia: "A mathematical model of a control valve".

[0008] According to the present invention there is provided a method for detecting a fault and for identifying the component in which the fault exists in an automatically operated valve assembly of the type having a plurality of components including at least an actuator, a valve member and a positioner controlled by a control signal, characterized in the following steps:

(a) defining a mathematical model for operation of the control valve assembly, the model being formed by at least one equation and including critical parameters for at least the actuator, the valve member and the positioner, each parameter describing the operation of one of the components of the valve assembly;
(b) collecting a plurality of values of the control signal and corresponding positions of the valve member;
(c) computing the critical parameters of the model on the basis of the measured data so that the model is reflecting the actual operation of the valve assembly; monitoring or watching the changes in said critical parameters on the basis of these adapted parameters; and locating a faulty component of the valve assembly by detecting a significant change of a corresponding critical parameter.

[0009] The method is based on identification of certain critical parameters of a mathematical model defining the dynamics and statics of a control valve, and on following the changes in these parameters. This makes is possible to detect and to conclude the faulted point. The advantages of the method is that the faulted operation and the location of the faulted component can be defined for instance by means of the control signal and the valve position data only.

[0010] In order to detect erosion damage of the closure member or possible blockage in the valve body, it is necessary

in addition to measure the pressure over the valve and to obtain data of the volume flow through the valve. This data can best be obtained through a data transfer bus from the measurement sensors.

[0011] The invention and its details are further described, by way of example, with reference to the accompanying drawings in which:

Fig. 1 shows schematically a measuring arrangement for the diagnostic system of an entire control valve assembly;
Fig. 2 shows a graph illustrating the correspondence between simulation carried out by means of identified parameters and measured values;
Fig. 3 shows graphically the relative change of the capacity coefficient of a blocked valve and
Fig 4 shows graphically the decrease of the relative capacity coefficient of a blocked valve.

[0012] The measuring arrangement of Fig. 1 makes it possible to detect and locate a fault affecting the dynamics of a control valve assembly and to detect possible erosion of a closure member of the valve or blockage of the valve body.

[0013] In Fig. 1, the closure member 1 of a valve 2 is provided with an actuator 3 which operates the valve by means of a cylinder 4. A digital positioner 5 is connected to the actuator. A volume flow sensor 6 is connected between a discharge pipe 7 and a field bus 8.

[0014] In order to define the dynamic operation of the valve, only data about the control signal i and the valve position h from the position transmitter is required. In addition, the detection of erosion of the closure member 1 and blockage of the valve body 2 requires pressure measurements p_1, p_2 for instance from the valve body 2 and flow data q from the volume flow sensor 6. The volume flow data q can be transmitted to the positioner 5 of the control valve for instance by means of the digital field bus 8. In this case, also the desired value of the control signal i is transmitted to the positioner 5 of the control valve by means of the digital field bus 8.

[0015] The locating of a fault affecting the dynamics of a control valve assembly will be described in the following.

[0016] The following equation can be found for the mathematical model of a quarter turn control valve provided with a cylinder-piston operated actuator:

$$\left(m_{red} \cdot \frac{dx}{d\psi} + J \cdot b(\psi)\right) \frac{d^2\psi}{dt^2} + m_{red} \cdot \frac{d^2x}{d\psi^2} \left(\frac{d\psi}{dt}\right)^2 + \left(f_m \cdot \frac{dx}{d\psi} + f_v \cdot b(\psi)\right) \frac{d\psi}{dt} + b(\psi) \cdot M_\mu - F_m(p_A, p_B) = 0 \qquad (1)$$

where

x =	distance travelled by the actuator piston
ψ =	rotational angle of the valve
t =	time
m_{red} =	reduced mass of the actuator piston
J =	combined inertia moment of the valve and the actuator
b =	actuator coefficient
M_μ =	friction moment of the valve
f_m =	attenuation coefficient of the actuator
f_v =	attenuation coefficient of the valve
F_m =	force applied to the actuator piston
p_A, p_B =	pressure levels of the actuator cylinder

[0017] Even if a quarter turn valve is discussed in this case, the method can be applied correspondingly to linear valves.

[0018] The movement of the actuator is controlled by means of the pressure levels of the cylinder which in the equation (1) are indicated by p_A, p_B. These can be computed by means of the following mathematical model defining the pressure level of the cylinder:

$$p_A = \Psi\ (k, V_A, T_a, m_a, A_A, x, R, M) \qquad (2)$$

$$P_B = \Theta\ (k, V_B, m_B, m_b, A_B, x, R, M) \qquad (3)$$

where

Ψ, Θ =	mathematical functions
k =	polytropic constant
V_A, V_B =	air volumes of the actuator cylinder
m_B =	mass of the air in the cylinder
T_a =	temperature of the air entering the cylinder
m_a =	mass flow of the air entering the cylinder
m_b =	mass flow of the air leaving the cylinder
A_A, A_B =	piston areas of the actuator
x =	the same as in equation (1)
R =	gas constant
M =	mole mass

[0019] The pressure levels are controlled by means of the mass flow entering and leaving the cylinder. The entering and leaving mass flows depend on the respective cross-sectional flow area of the regulating valve of the positioner. The cross-sectional flow area depends on the position of the spool or, in a poppet type construction, on the position of the seat of the regulating valve. Mathematically this can be written for one half of the actuator cylinder in the form:

$$m_a \approx f(A_a) \approx g(e) \qquad (4)$$

where

A_a =	the effective cross-sectional flow area of one half A of the regulating valve
e =	the position of the spool or the seat

[0020] An accurate mathematical model can be found for the functions f and g appearing in the equation.

[0021] The position of the spool or the seat of the regulating valve can be computed from the mathematical model of the regulation of the regulating valve. The following mathematical connection can be found for the conventional positioners based on the feedback of the valve position:

$$e = \Phi\ (k_p,\ i,\ h) \qquad (5)$$

where

Φ =	mathematical function
k_p =	gain of the positioner
i =	control signal
h =	opening of the control valve

[0022] The following is a decription of the method of locating the fault.

[0023] The method according to the invention is based on the identification of the critical parameters describing the various components of a control valve assemby, such as the positioner, the actuator and the valve itself. Identification is a method where the parameters of a mathematical model of a device are found by means of actual measurement data by fitting the model to the measured data. The greater the number of the parameters to be identified, the more difficult the identification in practice is. The measurement data is obtained either by means of a separate test or tests or merely by following the dynamic operation of the device during the operation process.

[0024] In the method of the invention, measurement data is required only from the position of the valve and from the control signal. If measurement data is collected also from the cylinder pressures of the actuator, it will assist in finding the location of the fault.

[0025] The method is based on the fact that a test or a series of tests is carried out for instance by means of a digital positioner in order to collect the necessary measurement data. The measurement data can also be collected directly from a control valve assembly in operation when the control signal coming from the regulator to the valve changes sufficiently. The data measured is recorded in the memory of the positioner for the identification.

[0026] The critical parameter or parameters for each component of a control valve assembly, that is the positioner,

the actuator and the valve itself, are identified from the above mathematical model by means of the measurement data. The critical parameters describing the operations of each component are chosen as the parameters to be identified.

[0027] The operation of a positioner is best described for instance by the gain k_p of the positioner. The extent of the output moment of an actuator again is expressed for instance by the actuator coefficient b. A mechanical fault of a valve is usually disclosed by friction so that for instance the friction load M_μ is the most suitable parameter for identification.

[0028] Fig. 2 illustrates the correspondence between simulation carried out with the identified parameters and the measured values. The curves show i/h as a function of time. Curve 11 presents input signal, curve 12 simulation and curve 13 measured data.

[0029] Fig. 2 shows measurement data produced by means of a sinusoidal control signal. The parameters of a simulating model made from a mathematical model were identified by means of the measurement data. The simulation carried out with the identified parameters corresponded well to the measured values as can be seen from Fig. 2.

[0030] The method can be made more accurate by measuring also the pressure levels p_A, p_B of the cylinder. Due to the increased measurement data, for instance the cross-sectional flow area of the regulating valve of the positioner can be identified. This can be further used for detecting for instance dirt in the regulating valve.

[0031] By following the change of the identified critical parameters, it is possible to watch by means of a conclusion program the change of a parameter describing the operation of each component. If changes or sliding as a function of time takes place in a certain parameter, it shows that essential changes take place in the operation of the component. The direction of the change shows if the operation of the control valve is going towards better or worse. If the value of the critical parameter of a certain component has changed sufficiently to a certain direction, it discloses the faulted component. In the concluding, it is also possible to use a diagram illustrating the change of an error between the control signal and the position of the control valve. A change in this diagram discloses if the error of a control valve is increasing or decreasing.

[0032] By means of the above method, it is possible by utilizing a simple conclusion program to automatically seek in which component of the control valve assembly operational changes take place and which component probably is the reason for instance to impaired control accuracy.

[0033] The finding of erosion and blockage of a control valve will be described in the following.

[0034] The method is based on reviewing the characteristic curve of a valve mounted in a process piping system. In this method, for instance the volume flow through the valve has to be measured by means of a volume flow sensor, in addition to the measuring of the pressure by means of pressure sensors in the valve. This data can best be made available for instance by means of a field bus.

[0035] The detection of eroding and blockage of a control valve is based for instance on pressure data measured in the valve body and volume flow data obtained for instance by means of a field bus which are utilized for instance in a digital positioner or in auxiliary equipment where the computing and analyzing take place.

[0036] Fig. 1 shows an example where position and pressure sensors connected to the valve body 1 are used for defining the opening h of the valve and the incoming pressure p_1 and discharge pressure p_2. This data combined with the flow quantity q obtained from the volume flow sensor 6 makes it possible to compute the set capacity coefficient Cv of a control valve.

[0037] The data obtained from the measurements is collected for instance in the digital positioner 5 where the capacity coefficient of the said valve can be computed by means of the equations set forth in standard IEC534 (ISAS75).

[0038] The results obtained are compared to a capacity coefficient measured in a laboratory. From the change in the capacity coefficient, it can be seen if the valve is eroding or being blocked. If there is erosion in the valve, the capacity coefficient tends to increase, particularly with small openings. Correspondingly, blockage will cause the capacity coefficient to decrease, particularly with greater openings.

[0039] A fault in an eroded or in a blocked valve will best be detected by following the change in the capacity coefficient of the valve in relation to the original capacity coefficient.

[0040] Fig. 3 shows the relative change of the capacity coefficient of an eroded valve as a function of the opening angle a. As can be seen from Fig. 3, the eroding can be very clearly seen, particularly at small opening angles. By following the relative change shown in Fig. 3 for instance by means of a digital positioner, it is possible to conclude the speed of erosion of the valve and to decide when the valve has to be changed at the latest.

[0041] Fig. 4 shows the change of the capacity coefficient of a blocked valve in relation to the original capacity coefficient. As can be seen from Fig. 4, the reduction of the capacoefficient, caused by blockage, can in the measured case be seen more clearly at greater opening angles.

[0042] The invention is not restricted to the above embodiments but it may vary within the scope of the claims. Instead of a rotational valve, the control valve can be also a linear valve. The actuator need not be cylinder-piston operated, it can be for instance electrically operated.

Claims

1. A method for detecting a fault and for identifying the component in which the fault exists in an automatically operated valve assembly of the type having a plurality of components including at least an actuator, a valve member and a positioner controlled by a control signal, characterized in the following steps:

   (a) defining a mathematical model for operation of the control valve assembly, the model being formed by at least one equation and including critical parameters for at least the actuator, the valve member and the positioner, each parameter describing the operation of one of the components of the valve assembly;
   (b) collecting a plurality of values of the control signal and corresponding positions of the valve member;
   (c) computing the critical parameters of the model on the basis of the measured data so that the model is reflecting the actual operation of the valve assembly; watching the changes in said critical parameters on the basis of these adapted parameters; and locating a faulty component of the valve assembly by detecting a significant change of a corresponding critical parameter.

2. A method as claimed in claim 1, wherein the control valve assembly includes a cylinder-piston operated actuator and the method that includes measuring cylinder pressures as part of the data.

3. A method according to claim 1, characterized in that the measured data includes data also from the incoming and discharge pressures (p_1, p_2) of the control valve and from the volume flow (q) through the control valve, and erosion of the closure member of the control valve or blockage of the valve body is detected.

4. A method according to claim 1, characterized in that the gain (k_p) of the positioner is used as the critical parameter for the positioner.

5. A method according to claim 1, characterized in that the actuator coefficient (b) is used as the critical parameter for the actuator.

6. A method according to claim 1, characterized in that the friction load (M_μ) of the control valve is used as the critical parameter for the control valve.

7. A method as claimed in any of claims 1 to 6, wherein said control valve assembly includes a quarter turn valve and a cylinder-piston operated actuator and wherein the following equation is used as the mathematical model:

$$\left(m_{red} \cdot \frac{dx}{d\psi} + J \cdot b(\psi)\right) \frac{d^2\psi}{dt^2} + m_{red} \cdot \frac{d^2x}{d\psi^2} \left(\frac{d\psi}{dt}\right)^2 +$$
$$\left(f_m \cdot \frac{dx}{d\psi} + f_v \cdot b(\psi)\right) \frac{d\psi}{dt} + b(\psi) \cdot M_\mu - F_m(p_A, p_B) = 0 \qquad (1)$$

where

x =	distance travelled by the actuator
ψ =	rotational angle of the valve
t =	time
m_{red} =	reduced mass of the actuator
J =	combined inertia moment of the valve and the actuator
b =	actuator coefficient
M_μ =	friction moment of the valve
f_m =	attenuation coefficient of the actuator
f_v =	attenuation coefficient of the valve
F_m =	force applied to the actuator piston
p_A, p_B =	pressure levels of the actuator cylinder

8. A method according to claim 7, **characterized** in that the pressure levels of the actuator cylinder are computed by means of the following mathematical model:

$$p_A = \Psi\,(k, V_A, T_a, m_a, A_A, x, R, M) \qquad (2)$$

$$P_B = \Theta\,(k, V_B, m_B, m_b, A_B, x, R, M) \qquad (3)$$

where

Ψ, Θ =	mathematical functions
k =	polytropic constant
V_A, V_B =	air volumes of the actuator cylinder
m_B =	mass of the air in the cylinder
T_a =	temperature of the air entering the cylinder
m_a =	mass flow of the air entering the cylinder
m_b =	mass flow of the air leaving the cylinder
A_A, A_B =	piston areas of the actuator
x =	the same as in equation (1)
R =	gas constant
M =	mole mass

9. A method according to claim 8, **characterized** in that the mass flow of the air entering one half of the actuator cylinder is computed from the following:

$$m_a \approx f(A_a) \approx g(e) \qquad (4)$$

where

f, g = mathematifal functions
A_a = the effective cross-sectional flow area of one half A of the regulating valve
e = the position of the spool or the poppet

10. A method according to claim 9, **characterized** in that the position of the spool or the poppet of the regulating valve of the positioner is computed from the following:

$$e = \Phi(k_p, i, h) \qquad (5)$$

where

Φ =	mathematical function
k_p =	gain of the positioner
i =	control signal
h =	opening of the control valve

11. An apparatus for detecting a fault in an automatically operated control valve assembly, the valve assembly having a plurality of components including at least a valve member (2), an actuator (3) and a digital positioner (5), as well as means for measuring, transferring, recording and processing data consisting of a plurality of values of the control signal (i) and corresponding values of the position (h) of the control valve, characterized in that

the means for processing the data includes a program including a mathematical model for operation of the control valve assembly, the model being formed by at least one equation and including critical parameters for at least the actuator (3), the valve merber (2) and the positioner (5), each parameter describing the operation of one of the components of the valve assembly; and that
the program is adapted for computing the critical parameters of the model on the basis of the measured data so that the model is reflecting the actual operation of the valve assembly; for watching the changes in said critical parameters on the basis of these adapted parameters; and for locating a faulty component of the valve

assembly by detecting a significant change of a corresponding critical parameter.

Patentansprüche

1. Verfahren zum Erkennen eines Fehlers und zum Identifizieren der Komponente, in der der Fehler auftritt, in einer automatisch betätigten Ventilanordnung des Typs, der mehrere Komponenten einschließlich wenigstens eines Aktuators, eines Ventilelementes und eines durch ein Steuersignal gesteuerten Positionierers besitzt, **gekennzeichnet durch** die folgenden Schritte:

   (a) Festlegen eines mathematischen Modells zur Arbeitsweise einer Steuerventilanordnung, wobei das Modell gebildet wird aus wenigstens einer Gleichung und kritische Parameter für wenigstens einen Aktuator, das Ventilelement und den Positionierer enthält, wobei jeder Parameter die Arbeitsweise von einer der Komponenten der Ventilanordnung beschreibt;

   (b) Sammeln von mehreren Werten des Steuersignals und korrespondierender Positionen des Ventilelements;

   (c) Berechnen der kritischen Parameter des Modells auf der Grundlage gemessener Daten, so dass das Modell die aktuelle Arbeitsweise der Ventilanordnung wiedergibt; Überwachen oder Beobachten der Änderungen in den kritischen Parametern auf der Grundlage von an diese angepassten Parametern; und Lokalisieren der fehlerhaften Komponente der Ventilanordnung durch Ermitteln einer signifikanten Änderung der korrespondierenden kritischen Parameter.

2. Verfahren wie in Anspruch 1 beansprucht, in welchem die Steuerventilanordnung einen Kolben-Zylinder-betätigten Aktuator einschließt und ein Verfahren, das die Messung des Zylinderdruckes als Teil der Daten einschließt.

3. Verfahren nach Anspruch 1,
   dadurch gekennzeichnet,
   dass die gemessenen Daten auch Daten aus den Eingangs- und Austrittsdrücken (p_1, p_2) des Steuerventils und aus dem Volumenstrom (q) durch das Steuerventil einschließt, und eine Abnutzung des Verschlusselementes des Steuerventils oder eine Verstopfung des Ventilkörpers ermittelt wird.

4. Verfahren nach Anspruch 1,
   dadurch gekennzeichnet,
   dass die Verstärkung (k_p) des Positionierers als kritischer Parameter für den Positionierer verwendet wird.

5. Verfahren nach Anspruch 1,
   dadurch gekennzeichnet,
   dass der Aktuatorkoeffizient (b) als kritischer Parameter für den Aktuator verwendet wird.

6. Verfahren nach Anspruch 1,
   dadurch gekennzeichnet,
   dass die Reibungsbelastung (M_μ) des Steuerventils als kritischer Parameter für das Steuerventil verwendet wird.

7. Verfahren nach einem der vorstehenden Ansprüche 1 bis 6, in welchem die Steuerventilanordnung ein Vierteldrehungsventil und einen Kolben-Zylinder-betätigten Aktuator einschließt und in welchem die folgende Gleichung als mathematisches Modell benutzt wird;

$$(m_{red} \times \frac{dx}{d\psi} + J \times b(\psi)) \frac{d^2\psi}{dt^2} + m_{red} \times \frac{d^2x}{d\psi^2} (\frac{d\psi}{dt})^2 +$$

$$(f_m \times \frac{dx}{d\psi} + f_v \times b(\psi)) \frac{d\psi}{dt} + b(\psi) \times M_\mu - F_m(p_A, p_B) = 0 \qquad (1)$$

wobei

x =	vom Aktuatorkolben zurückgelegte Distanz
ψ =	Rotationswinkel des Ventils

$t =$ Zeit
$m_{red} =$ reduzierte Masse des Aktuatorkolbens
$J =$ kombiniertes Anfangsmoment des Ventils und des Aktuators
$b =$ Aktuatorkoeffizient
$M_{\mu} =$ Reibungsmoment des Ventils
$f_m =$ Beschleunigungskoeffizient des Aktuators
$f_v =$ Beschleunigungskoeffizient des Ventils
$F_m =$ auf den Aktuatorkolben ausgeübte Kraft
$p_A, p_H =$ Druckniveaus des Aktuatorzylinders

8. Verfahren nach Anspruch 7,
dadurch gekennzeichnet,
dass die Druckniveaus des Aktuatorzylinders mittels des folgenden mathematischen Modells errechnet werden:

$$p_A = \Psi\ (k, V_A, T_a, m_a, A_A, x, R, M) \quad (2)$$

$$P_B = \theta\ (k, V_B, m_B, m_b, A_B, x, R, M) \quad (3)$$

wobei

$\psi, \theta =$ mathematische Funktionen
$k =$ polytrope Konstante
$V_A, V_B =$ Luftvolumen des Aktuatorzylinders
$m_B =$ Luftmasse in dem Zylinder
$T_a =$ Temperatur der Luft, die den Zylinder betritt
$m_a =$ Massenfluss der Luft, die den Zylinder betritt
$m_b =$ Massenfluss der Luft, die den Zylinder verlässt
$A_A, A_B =$ Kolbenflächen des Aktuators
$x =$ ebenso wie in Gleichung (1)
$R =$ Gaskonstante
$M =$ Molmasse

9. Verfahren nach Anspruch 8,
dadurch gekennzeichnet,
dass der Massenfluss an Luft, der die eine Hälfte des Aktuatorzylinders betritt, aus dem Folgenden errechnet wird:

$$m_a \approx f(A_a) \approx g(e) \quad (4)$$

wobei

$f, g =$ mathematische Funktionen
$A_a =$ effektive Querschnittsflussfläche der einen Hälfte A des Regelventils
$e =$ Position der Spule oder des Tellers

10. Verfahren nach Anspruch 9,
dadurch gekennzeichnet,
dass die Position der Spule oder des Tellers des Regulierungsventils des Positionierers aus dem Folgenden berechnet wird:

$$e = \phi\ (k_p, i, h) \quad (5)$$

wobei

ϕ = mathematische Funktion
k_p = Verstärkung des Positionierers
i = Steuersignal
h = Öffnung des Steuerventils

11. Vorrichtung zum Ermitteln eines Fehlers in einer automatisch betätigten Steuerventilanordnung, wobei die Ventilanordnung mehrere Komponenten einschließlich wenigstens eines Ventilelementes (2), eines Aktuators (3) und eines Digitalpositionierers (5) einschließt sowie auch Mittel zum Messen, Übertragen, Aufzeichnen und Verarbeiten von Daten, die aus mehreren Werten eines Steuersignals (i) und entsprechenden Werten der Position (h) des Steuerventils bestehen,
dadurch gekennzeichnet,
dass die Mittel zum Verarbeiten der Daten ein Programm einschließlich eines mathematischen Modells zur Betriebsweise der Steuerventilanordnung einschließen, wobei das Modell aus wenigstens einer Gleichung gebildet ist und kritische Parameter für zumindest den Aktuator (3), das Ventilelement (2) und den Positionierer (5) einschließt, wobei jeder Parameter die Betriebsweise einer der Komponenten der Ventilanordnung beschreibt; und **dass** das Programm angepasst ist zur Berechnung der kritischen Parameter des Modells auf der Grundlage der gemessenen Daten, so dass das Modell die aktuelle Betriebsweise der Ventilanordnung wiedergibt; zur Beobachtung der Änderungen in den kritischen Parametern auf der Grundlage dieser angepassten Parameter; und zum Lokalisieren einer fehlerhaften Komponente der Ventilanordnung durch Ermitteln einer signifikanten Änderung eines entsprechenden kritischen Parameters.

Revendications

1. Procédé de détection d'un défaut et d'identification du composant dans lequel est présent le défaut dans un ensemble de soupape à actionnement automatique du type possédant une pluralité de composants comprenant au moins un actionneur, une pièce de soupape et un positionneur commandé par un signal de commande, caractérisé par les étapes suivantes :

   a) la définition d'un modèle mathématique pour le fonctionnement de l'ensemble de soupape de commande, le modèle étant formé d'au moins une équation et comprenant des paramètres critiques pour au moins l'actionneur, la pièce de soupape et le positionneur, chaque paramètre décrivant le fonctionnement de l'un des composants de l'ensemble de soupape ;

   b) le regroupement d'une pluralité de valeurs du signal de commande et des positions correspondantes de la pièce de soupape ; et

   c) le calcul des paramètres critiques du modèle sur la base des données mesurées de telle façon que le modèle reflète le fonctionnement réel de l'ensemble de soupape ; la surveillance des variations desdits paramètres critiques sur la base de ces paramètres adaptés ; et la localisation d'un composant défectueux de l'ensemble de soupape en détectant une variation significative d'un paramètre critique correspondant.

2. Procédé selon la revendication 1, selon lequel l'ensemble de soupape de commande comprend un actionneur activé par cylindre/piston et le procédé comprenant la mesure des pressions de cylindre faisant partie des données.

3. Procédé selon la revendication 1, caractérisé en ce que les données mesurées comprennent, de même, des données des pressions entrantes et de décharge (p_1, p_2) de la soupape de commande et du débit volumique (q) à travers la soupape de commande, et l'usure de la pièce d'obturation de la soupape de commande ou un blocage du corps de soupape est détectée.

4. Procédé selon la revendication 1, caractérisé en ce que le gain (k_p) du positionneur est utilisé comme paramètre critique du positionneur.

5. Procédé selon la revendication 1, caractérisé en ce que le coefficient d'actionneur (b) est utilisé comme paramètre critique pour l'actionneur.

6. Procédé selon la revendication 1, caractérisé en ce que la charge de frottement (M_μ) de la soupape de commande est utilisée comme paramètre critique pour la soupape de commande.

7. Procédé selon l'une quelconque des revendications 1 à 6, selon lequel ledit ensemble de soupape de commande comprend une soupape en quart de tour et un actionneur à cylindre/piston, et selon lequel on utilise l'équation suivante comme modèle mathématique :

$$\left(m_{red} \bullet \frac{dx}{d\psi} + J \bullet b(\psi)\right) \frac{d^2\psi}{dt^2} + m_{red} \bullet \frac{d^2x}{d\psi^2} \left(\frac{d\psi}{dt}\right)^2 + \left(f_m \bullet \frac{dx}{d\psi} + f_v \bullet b(\psi)\right) \frac{d\psi}{dt} + b(\psi) \bullet M_\mu - F_m(p_A, p_B) = 0 \qquad (1)$$

où

x = la distance parcourue par l'actionneur

ψ = l'angle de rotation de la soupape

t = le temps

m_{red} = la masse réduite de l'actionneur

J = le moment d'inertie combiné de la soupape et de l'actionneur

b = le coefficient d'actionneur

M_μ = le moment de frottement de la soupape

f_m = le coefficient d'atténuation de l'actionneur

f_v = le coefficient d'atténuation de la soupape

F_m = l'effort appliqué au piston d'actionneur

p_A, p_B = les niveaux de pression du cylindre d'actionneur.

8. Procédé selon la revendication 7, caractérisé en ce que les niveaux de pression du cylindre d'actionneur sont calculés au moyen du modèle mathématique suivant :

$$p_A = \Psi (k, V_A, T_a, m_a, A_A, x, R, M) \qquad (2)$$

$$pB = \theta(k, V_B, m_B, m_b, A_B, x, R, M) \qquad (3)$$

où

Ψ, θ = des fonctions mathématiques

k = une constante polytropique

V_A, V_B = les volumes d'air du cylindre d'actionneur

m_B = la masse d'air dans le cylindre

T_a = la température de l'air entrant dans le cylindre

m_a = le débit massique de l'air entrant dans le cylindre

m_b = le débit massique de l'air quittant le cylindre

A_A, A_B = les surfaces de piston de l'actionneur

X = le même que dans l'équation (1)

R = une constante de gaz

M = la masse molaire.

9. Procédé selon la revendication 8, caractérisé en ce que le débit massique de l'air pénétrant dans une moitié du cylindre d'actionneur est calculé à partir de la formule suivante :

$$m_a \approx f(A_a) \approx g(e) \tag{4}$$

où

f, g = des fonctions mathématiques

A_a = la surface effective de section transversale d'écoulement d'une moitié A de la soupape de régulation

e = la position du tiroir ou du champignon.

10. Procédé selon la revendication 9, caractérisé en ce que la position du tiroir ou du champignon de la soupape de régulation du positionneur est calculée à partir de la formule suivante :

$$e = \Phi(k_p, h, i) \tag{5}$$

où

Φ = une fonction mathématique

k_p = le gain du positionneur

i = un signal de commande

h = l'ouverture de la soupape de commande.

11. Dispositif pour la détection d'un défaut dans un ensemble de soupape de commande à actionnement automatique, l'ensemble de soupape possédant une pluralité de composants comprenant au moins une pièce de soupape (2), un actionneur (3) et un positionneur numérique (5) ainsi que des moyens pour mesurer, transférer, enregistrer et traiter des données comprenant une pluralité de valeurs du signal de commande (i) et des valeurs correspondantes de la position (h) de la soupape de commande, caractérisé en ce que :

- le moyen de traitement des données comprend un programme comprenant un modèle mathématique pour le fonctionnement de l'ensemble de soupape de commande, le modèle étant formé d'au moins une équation et comprenant des paramètres critiques pour au moins l'actionneur (3), la pièce de soupape (2) et le positionneur (5), chaque paramètre décrivant le fonctionnement de l'un des composants de l'ensemble de soupape ; et
- le programme est prévu pour le calcul des paramètres critiques du modèle sur la base des données mesurées de telle façon que le modèle reflète le fonctionnement réel de l'ensemble de soupape ; la surveillance des variations desdits paramètres critiques sur la base de ces paramètres adaptés ; et la localisation d'un composant défectueux de l'ensemble de soupape en détectant une variation significative d'un paramètre critique correspondant.

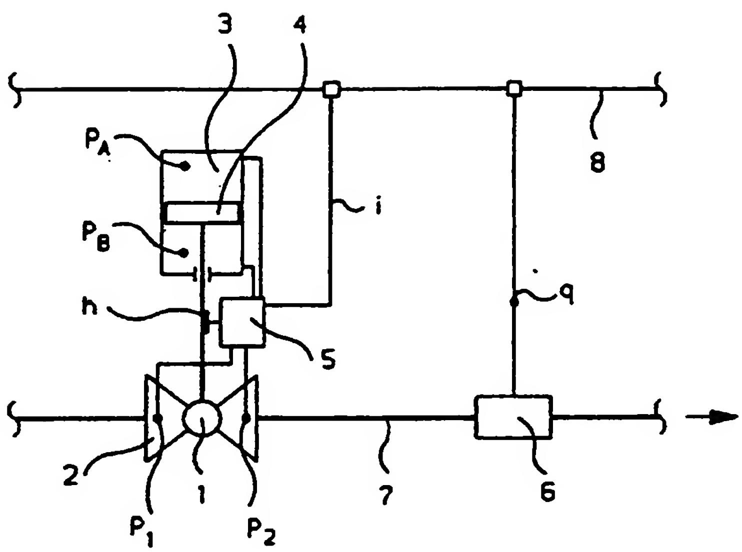
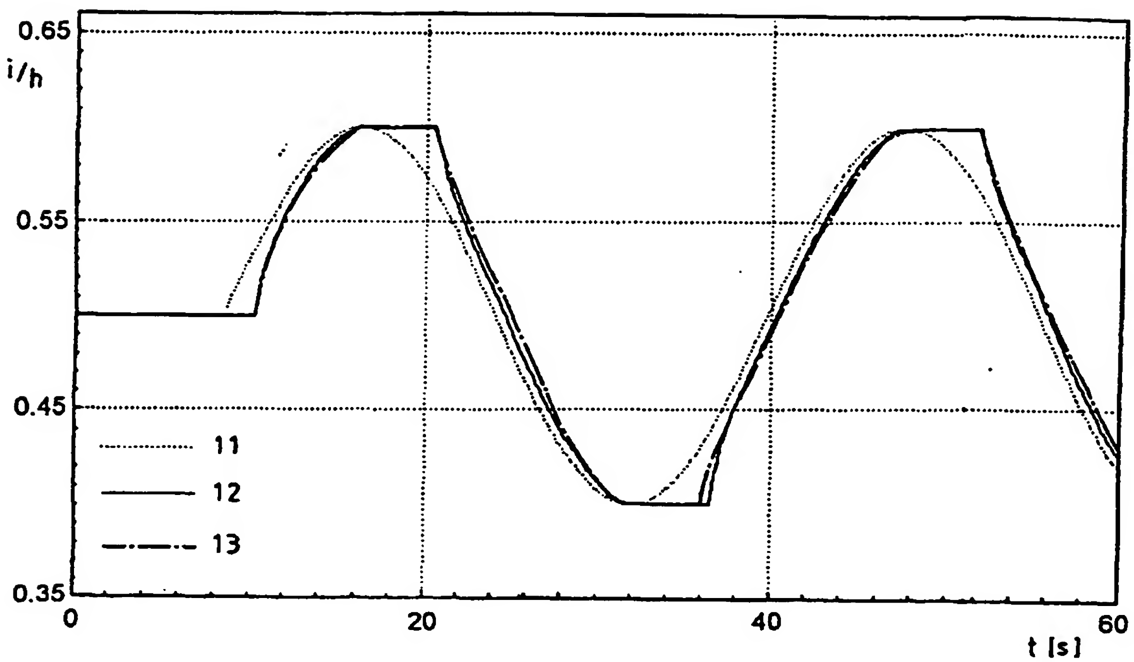
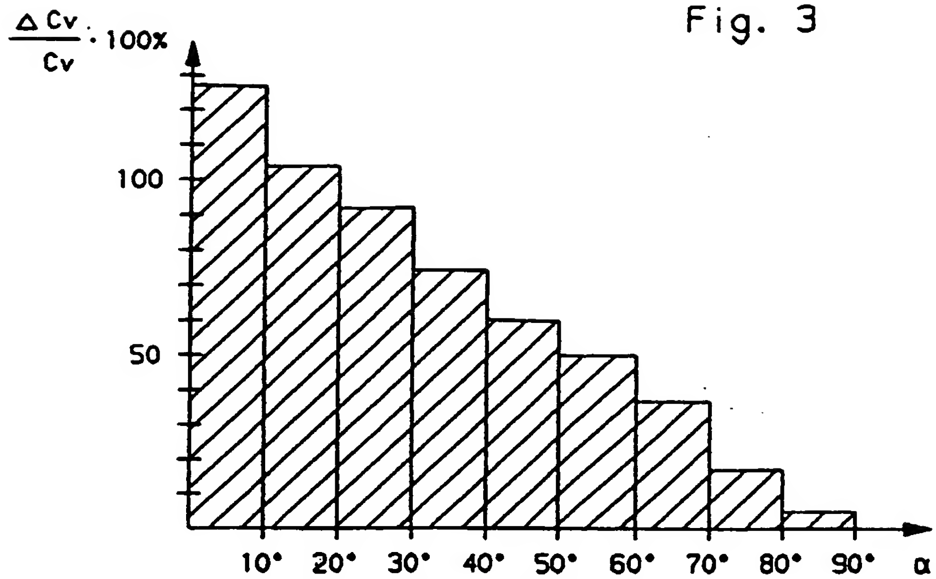


Fig. 1

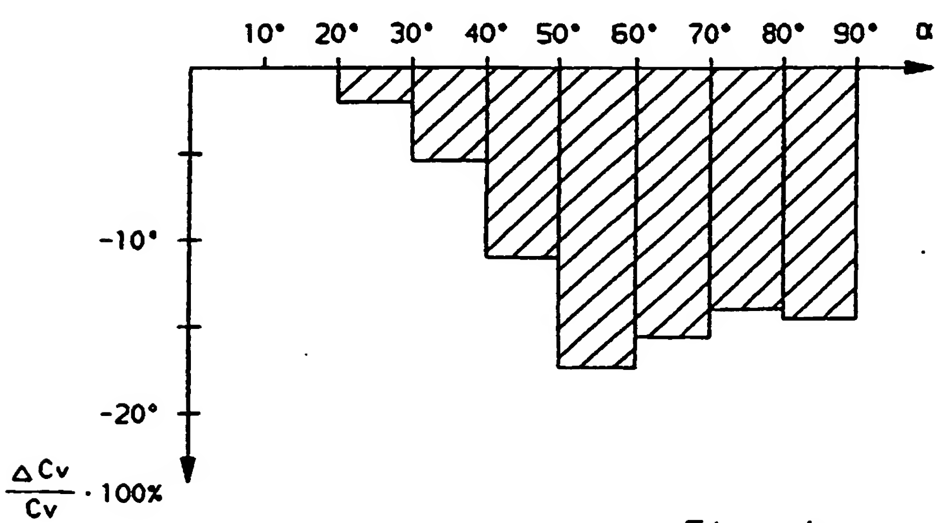
Fig. 2





ΔCv/Cv · 100%
100
50
10° 20° 30° 40° 50° 60° 70° 80° 90° α

Fig. 3



10° 20° 30° 40° 50° 60° 70° 80° 90° α
-10°
-20°
ΔCv/Cv · 100%

Fig. 4